Sand Dispersal Pattern within Panna Formation in Central Graben, Bombay Offshore Basin: A Model Based Approach

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Summary

Panna Formation forms the oldest Tertiary sedimentary unit of the Bombay Offshore Basin and attains its significance for hydrocarbon exploration due to the presence of source, reservoir and seal within it. Panna shales and coals are acknowledged as the established source rock in the basin. In addition they also act as vertical and lateral seal for the coarser clastic reservoirs embedded within them. The development of the reservoir facies throughout the basin is uncertain because of the lenticular nature of the sand deposition. Hence understanding the distribution of the reservoir facies within the formation is essential for fulfilling the exploration requirements.

For Panna exploration, a 3D seismic volume of NE Panna within Central Graben in Heera Panna Bassein block of Bombay Offshore Basin, was evaluated along with the other available geosceintific data. The present study has brought out the sand dispersal pattern within Panna Formation from the attributes of 3D seismic and well data. Alluvial fans/fluvial channels have been mapped as main processes for deposition of Panna sandstones. A depositional model showing sand inputs from west and south-west have been reconstructed.

Introduction

The present study is based on the evaluation of 3D seismic data falling within the Central Graben of the Heera Panna Bassein Block of Bombay offshore basin (Fig-1).

It encompasses major part of Central Graben where huge thickness of Panna sediments were deposited during Late Paleocene to Lower Eocene time. Panna Formation forms an independent petroleum system as Panna shales are established source rock in the basin and widespread occurrence of thick shales within Panna, are excellent vertical and lateral seals. Within this part of the basin Panna sandstones are known producers but in the 3D area Panna pay zones couldn't be found by drilled wells D, E and F (Fig-1). The existence of locales having suitable reservoir facies is uncertain in the area. The present study focuses to understand the distribution of such reservoir facies in time and space within Panna which ultimately result in reducing the risk of exploration.

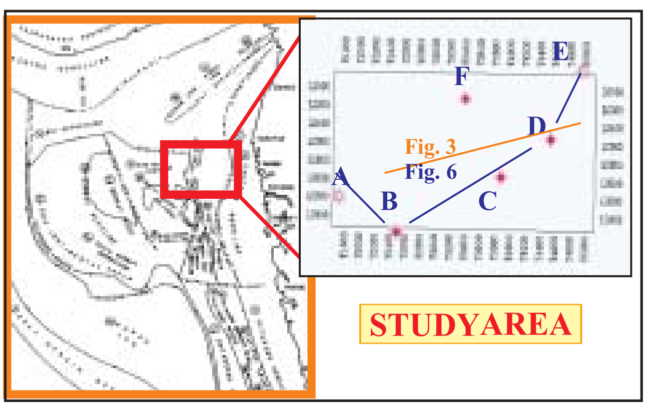

Fig-1: Location map of the study area

General geology of Panna formation

The Bombay Offshore Basin is a pericratonic rift (Biswas, 1982, 1987, Naini and Talwani, 1982) characterized by sets of longitudinal extensional faults giving rise to series of horst and graben features. During the initial time of rifting these half grabens accumulated thick pile of clastic sediments derived from the adjacent basaltic and granitic horst blocks. The onset of Panna sedimentation is marked by the deposition of trap wash and sediments derived from granite erosion during Paleocene. A wide spread fluvial system dominated the area during Late Paleocene to Early Eocene time depositing sand, silt, shale and coal and hosts the main producing horizons. It is followed by wide spread marine transgression leading to the deposition of marine shales at the top. Huge thickness of Mid Eocene to recent sediments consisting of Bassein, Mukta, Heera, Alibag, Bombay, Mahim, Tapti and Chinchini Formations were also deposited in this area over the Panna Formation (Fig-2).

Data interpretation and analysis

Most fundamental and basic approach was adopted for understanding the sand distribution pattern within Panna Formation in the study area as given below

- Understanding the regional tectonics and prevailing basement configuration vis-a-vis perceived paleodrainage systems during deposition of Panna sediments from the published and unpublished literatures.
- Mapping of Tops of Panna, Basement and five markers within Panna ie Panna-1 Panna-2,Panna-3 Panna-4 and Panna-pay-Top (Bottom to top) from 3D seismic as well as the available log data (Fig- 3)
- Understanding the paleostructures from isochronopach maps of Panna and different units within it.

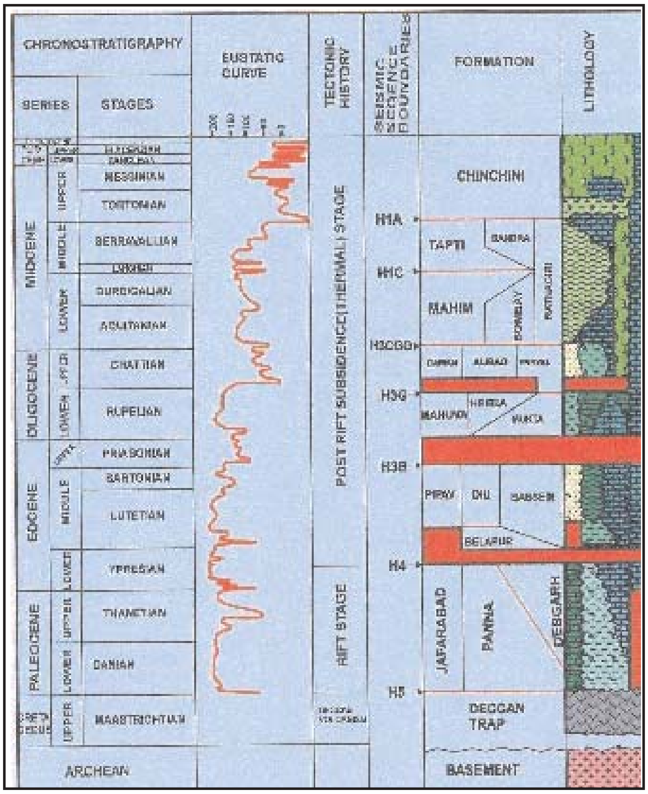

Fig-2: Generalized Stratigraphy of Bombay offshore basin

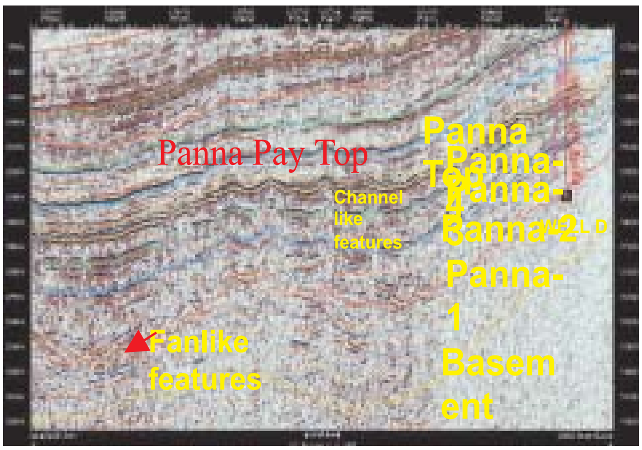

Fig-3 East west arbitrary line passing through the Well-D showing correlated horizons and other features within Panna formation The location of profile is shown in Fig-1.

Identification of reservoir facies within Panna Formation from different seismic attributes as well as log facies analysis, supported by the conceptual geological model prepared for understanding the possible sand dispersal pattern during Panna deposition.

Present day configuration

Mapping of the different stratigraphic markers within the 3D data volume has given ample scope to understand the structural and stratigraphic configuration of the area. The major tectonic elements are the NNE-SSW, NW-SE and WNW-ESE trending faults which dissect the area forming highs and lows. In the central part of the area a NNE-SSW trending Mahim arch divide the Central graben into eastern and western lows. In the eastern part of the eastern low a west hading normal fault separates the Eastern Homocline from the Central graben (Fig- 4) The Central graben is filled with thick clastic/carbonate sediments ranging from Paleocene to Recent.

Paleo structural analysis

Though the paleostructural analysis of the study area requires to be done in consonance with the regional picture, here an attempt has been made to evolve the structural picture vis-à-vis the depositional history for Panna formation over the area. The isochronopach map between Basement to Panna top (Fig-5) reveals the paleotopography of the basement over which the Panna Formation and its subunits were deposited. The map depicts that the general slope was towards north and northeast with two depocenters in the western and eastern lows.

Facies analysis and mapping of reservoir rocks

Electrolog facies analysis

The electrolog facies analysis along E-W profile was carried out to know the spatio temporal distribution of the associated lithofacies within Panna formation (Fig-6)

The typical Deccan Trap/weathered basalts is identified by sharp fall in gamma and increase in the resistivity logs (well **E** and **A**). This is overlain by the clastic sediments of Panna

Fig-4 Time structure map on top of Panna Formation showing present day tectonic configuration.

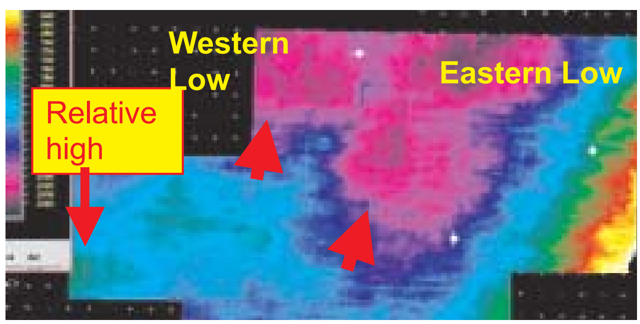

Fig-5 Isochronopach map of Panna Formation showing paleotopography of Basement

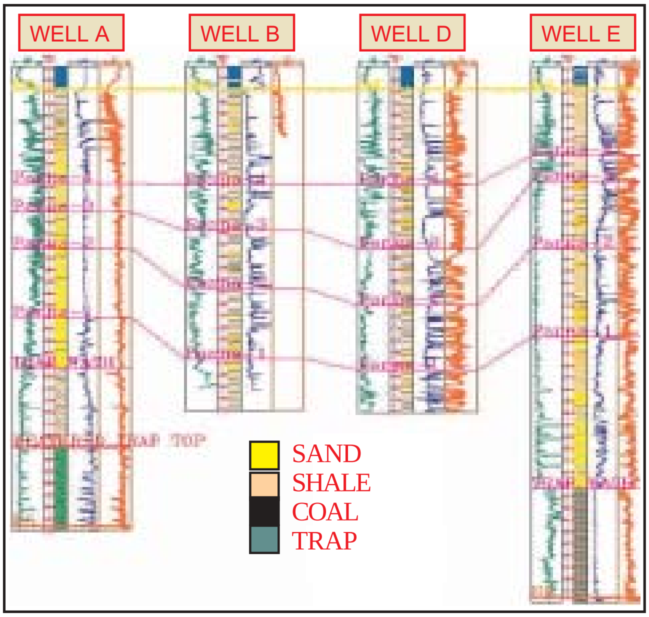

Fig-6 Electrolog correlation along well A,B,D and E (The profile is Flattened at Panna Top).The location of profile is shown in Fig-1.

Formation characterized by variations in gamma, resistivity, density, porosity and sonic logs, corresponding to sand, shale, siltstone and coal. More than 870 m of Panna Formation was encountered in the well **E**. The Panna Formation thickens towards west and is expected to be more than 1300 m in the Central Graben. Towards the Eastern Homocline it consists dominantly of shales, carbonaceous shales and coals with occasional siltstone and fine sandstone bands (Well D and E). But towards west, at the PE Structure, this unit is dominantly sandstone with siltstones, shales and coals bands (Well A). The top part of the Panna Formation is thick shale (60 to 100 m) with occasional coal streaks and is persistent in all the drilled wells.

Seismic facies analysis

The seismic sequences within Panna Formation were analysed by using seismic and log attribute extraction and their calibration at wells. 3-D visualization, seismic inversion and spectral decomposition were used to understand the spatial and temporal distribution of the zones within the identified intervals.

RMS amplitude between H5 and H4 (Panna Formation) (Fig-7) shows anomalous high amplitude towards west and south west part of area. At drilled wells **D** and **F**, towards eastern and northern part of area, anomalies and sands both are almost absent within drilled section of Panna Formation. Mainly shales and coals are encountered within Panna Formation in these wells (Fig. 6). RMS amplitude maps within individual units of Panna Formation gave similar high amplitude towards west and south west(Fig. 8, 9, 10). These anomalies are interpreted to be caused by increased sand contents towards west and south west on the basis of following observations:

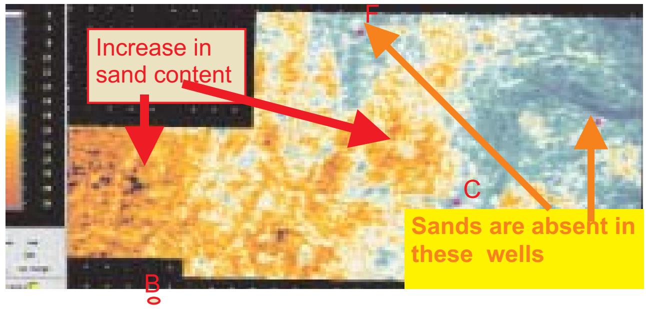

Fig-7 RMS amplitude map between Basement (H5) and Panna Top (H4) showing high amplitude towards west.

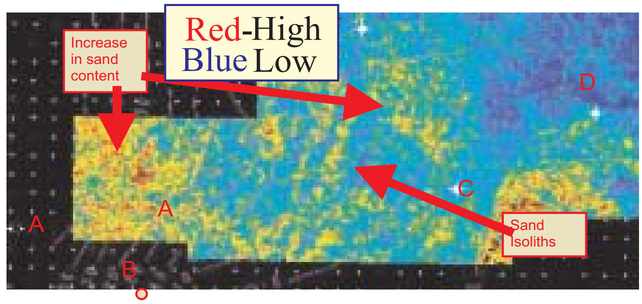

Fig-8 RMS amplitude with overlay of Sand Isolith in the interval Panna-2-Panna-3. Both RMS amplitude and sand thickness increasing towards west

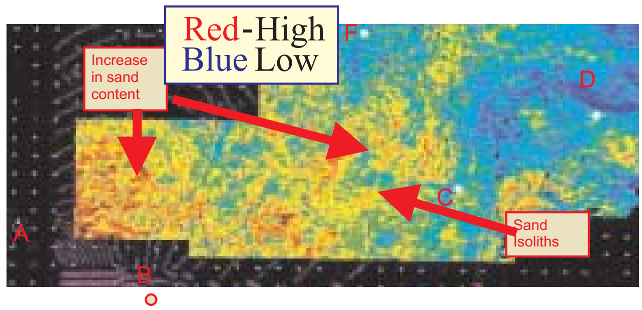

Fig- 9 RMS amplitude with overlay of Sand Isolith in the interval Panna-3-Panna -4. Both RMS amplitude and sand thickness increasing towards west

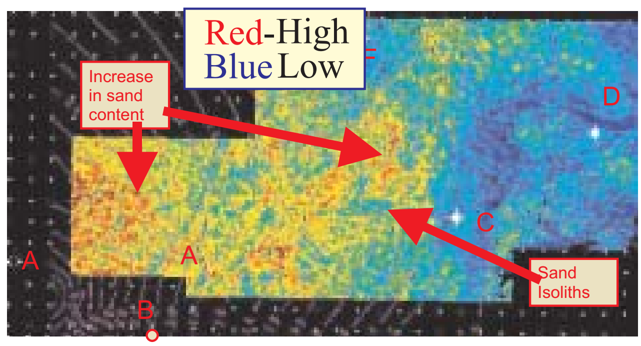

Fig-10 RMS amplitude with overlay of Sand Isolith in the interval Panna-4-Panna Top(H4). Both RMS amplitude and sand thickness increasing towards west

- Within Panna Formation (Basal Clastics) more than 250 m sand has been encountered in the well **A** which is also hydrocarbon bearing. These sands seem to have been deposited in a terrestrial environment as debris flow /Fan at places and alluvial to fluvial channels in most of the area

- Sand isolith maps overlain with RMS amplitudes for intervals Panna-2 to Panna-3 (Figure 8), Panna-3 to Panna-4 (Figure 9), and Panna-4 to H4 (Figure 10) show increase in amplitude and sand thickness towards west from east.

- The sweetness attribute within 0 to -20 ms window with reference to Panna-3 shows high values oriented in channel like features (Fig-11).

- Within Upper part of Panna Formation (Unit V:-Panna-4 to H4) a reflector equivalent to Panna-pay-top in well A was correlated within 3D area. The 3D voxel image of this reflector (Fig 12) shows Fan features in western part and meandering channel features in central part.

- A 40 Hz spectral decomposition slice within -10 to +10 ms window with reference to Panna-pay top reflector enhances the geometry of mapped channel (Fig 13).

The impedance map within 0 to +12 ms window with reference to Panna-pay top reflector shows high impedance within the mapped channel (Fig 14). High impedance coupled with high amplitude (Fig 12 and 14) suggests the presence of sandy facies within the channel.

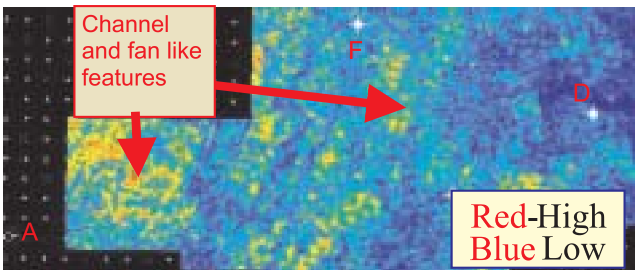

Fig 11 The sweetness attribute within 0 to -20 ms window with reference to Panna-3..

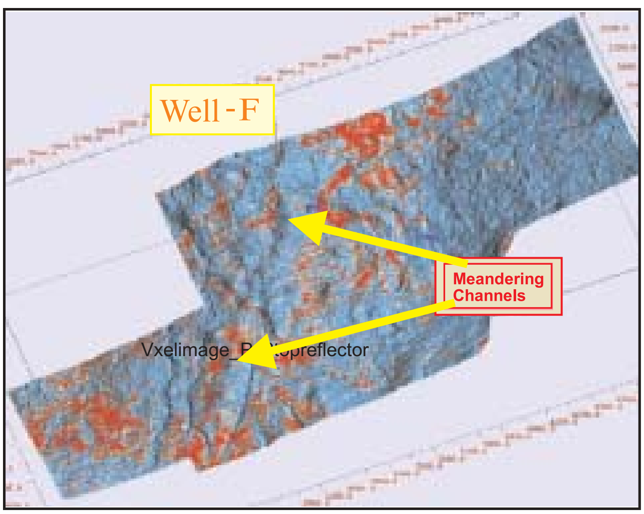

Fig 12: 3D Voxel image of Panna pay top reflector showing channel like features

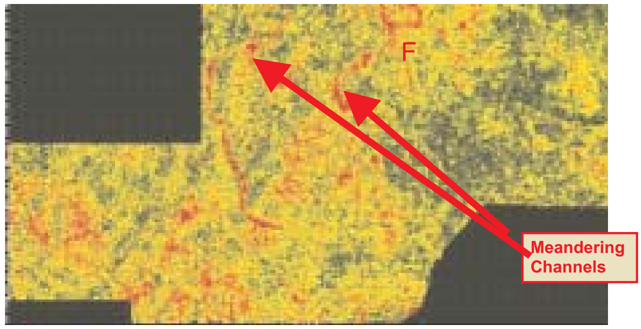

Fig 13: Spectral decomposition 40Hz amplitude slice within -10 to +10 ms window with reference to Pe2Top reflector.

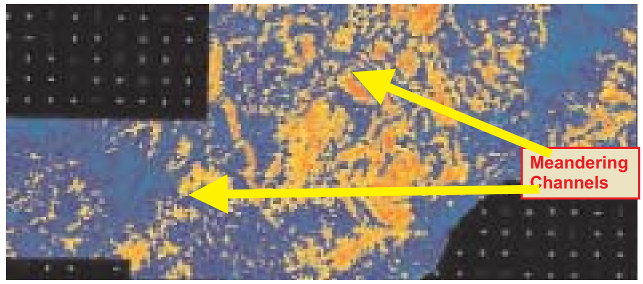

Fig 14: Impedance map within 0 to +12 ms window with reference to Panna pay top reflector

Discussion and Results

Depositional environments, geometries and probable litho facies within Panna Formation have been interpreted from the seismic attributes, log facies and paleostructural analysis. Based on inferences drawn from 3D data interpretation a geological model has been conceptualized for the deposition of the coarser clastics within Panna Formations. The granite horst blocks to the west and south west acted as the provenance for these sand inputs in the form of alluvial fans and these coarser clastics are redistributed by the axial channels flowing from the south towards the main depocenter in Central graben (Fig-15). A east west schematic geological section prepared through

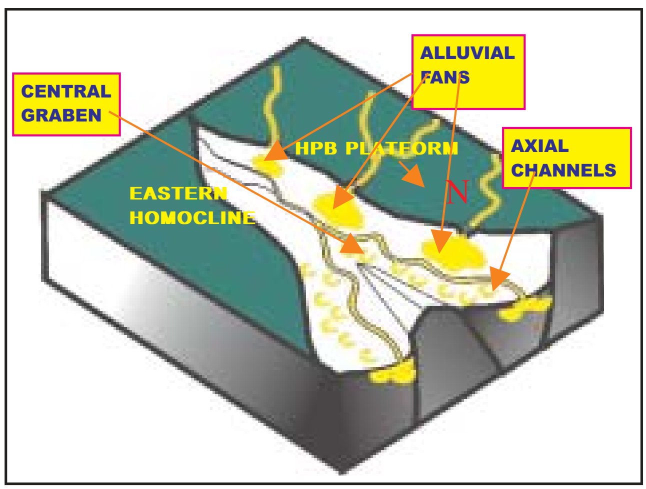

Fig:15 Conceptual depositional model showing alluvial fans and axial channels during Panna deposition within central graben

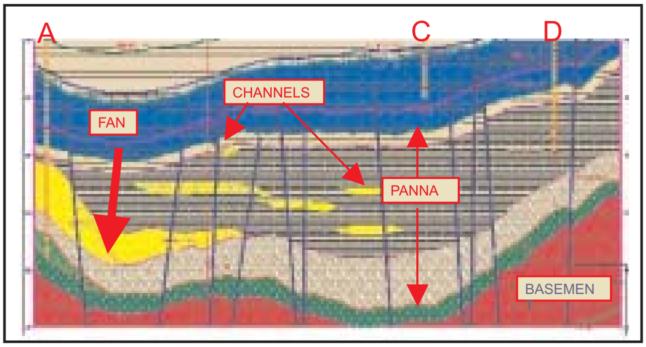

Fig-16 Schematic Geological section through Wells A,C and D showing the sand dispersal pattern.

drilled wells to demonstrate the possible sand dispersal pattern (Fig16)

Conclusion

The 3D data has been evaluated with application of seismic attribute analysis, seismic inversion, 3D visualization and spectral decomposition with integration of log data analysis. Sand dispersal pattern within the area has been brought out and depositional model has been constructed for Panna Formation. Sand inputs from the west and south west from the granitic basement, by different mechanisms like alluvial fans and axial channels have been envisaged. This study will help in reducing the risk of Panna exploration.

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The views expressed in this paper are exclusively of the authors and need not necessarily match with official views of ONGC.

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